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DOMESTIC PREPAREDNESS PROGRAM: LIQUID SULFUR MUSTARD
AND SARIN CHALLENGE/VAPOR PENETRATION SWATCH TESTING
OF TYCHEM 9400 COVERALL
MODEL 94150

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February 1999

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Aberdeen Proving Ground, MD 21010-5424

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13. ABSTRACT (Maximum 200 words) A Tychem 9400 Coverall, Model 94150 (Lakeland Industries, Somerville, AL) had swatches taken from six sample positions. These swatches were tested against sulfur mustard (HD) and sarin (GB) in accordance with U.S. Army Edgewood Research, Development and Engineering Center's (ERDEC) modified static diffusion procedure, which was derived from Test Operations Procedure (TOP) 8-2-501.		
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Preface

The work described in this report was authorized under the Expert Assistance (Personal Protective Equipment Evaluation) Program for the U. S. Army Edgewood Research, Development and Engineering Center (ERDEC)* Program Director for Domestic Preparedness. The work was started in April 1998 and completed in June 1998.

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* Now known as the U.S. Army Edgewood Chemical Biological Center (ECBC).

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DOMESTIC PREPAREDNESS PROGRAM: LIQUID SULFUR MUSTARD AND
SARIN CHALLENGE/VAPOR PENETRATION SWATCH TESTING
OF TYCHEM 9400 COVERALL
MODEL 94150

1. INTRODUCTION

Under the Domestic Preparedness (DP) Expert Assistance (Personal Protective Equipment (PPE) Evaluation) Program, the U. S. Army Edgewood Research, Development and Engineering Center (ERDEC)* was tasked to perform testing of swatches taken from commercially-available Level B suits currently being used by emergency responders from cities involved in this program. The testing was performed by the Design Evaluation Group, Surety Team, Methodology, Instrumentation and Test Office, Engineering Directorate. The test procedure was jointly developed and agreed upon by ERDEC and the U. S. Army Natick, Research, Development and Engineering Center (NRDEC) (written communication, M. Chin, NRDEC, 1 May 97).

2. MATERIALS AND METHODS

2.1 Suit Description.

The Tychem 9400 coverall was manufactured by Lakeland Industries, (Somerville, AL) and was bright yellow in color. The model number was 94150. Figure 1 is a digital photograph of the label found inside the suit.

2.2 Swatch Preparation.

The day before testing was scheduled to begin, the suit was picked up from Mask Issue and transported to the laboratory. The suit was folded up for transport and was hung on a hanger once in the laboratory. The suit was stored this way during and after testing.

The swatch locations to be sampled were given in the PPE Test Team Work Contract for Level A Ensembles (written communication, R. Belmonte, Engineering Directorate, ERDEC, 25 June 1997). These swatch sampling locations were listed as suit material (SM), suit seam (SS), visor material (VM), zipper/suit material seam (ZP), glove (GL), and visor material/suit material seam (SV). The coverall did not have a visor or gloves but did have boots. The decision was made to take swatches from these six locations; the crotch seam (CS), boot material (BM), boot seam (BS), outer zipper/material interface (OZ), SM, and SS. The swatches were normally cut the day before testing and conditioned overnight at the test conditions. For a Monday test, swatches were cut Friday and conditioned over the weekend. Normally, the swatches would be laid in the environmental cabinet for conditioning.

* Now known as the U.S. Army Edgewood Chemical Biological Center (ECBC).

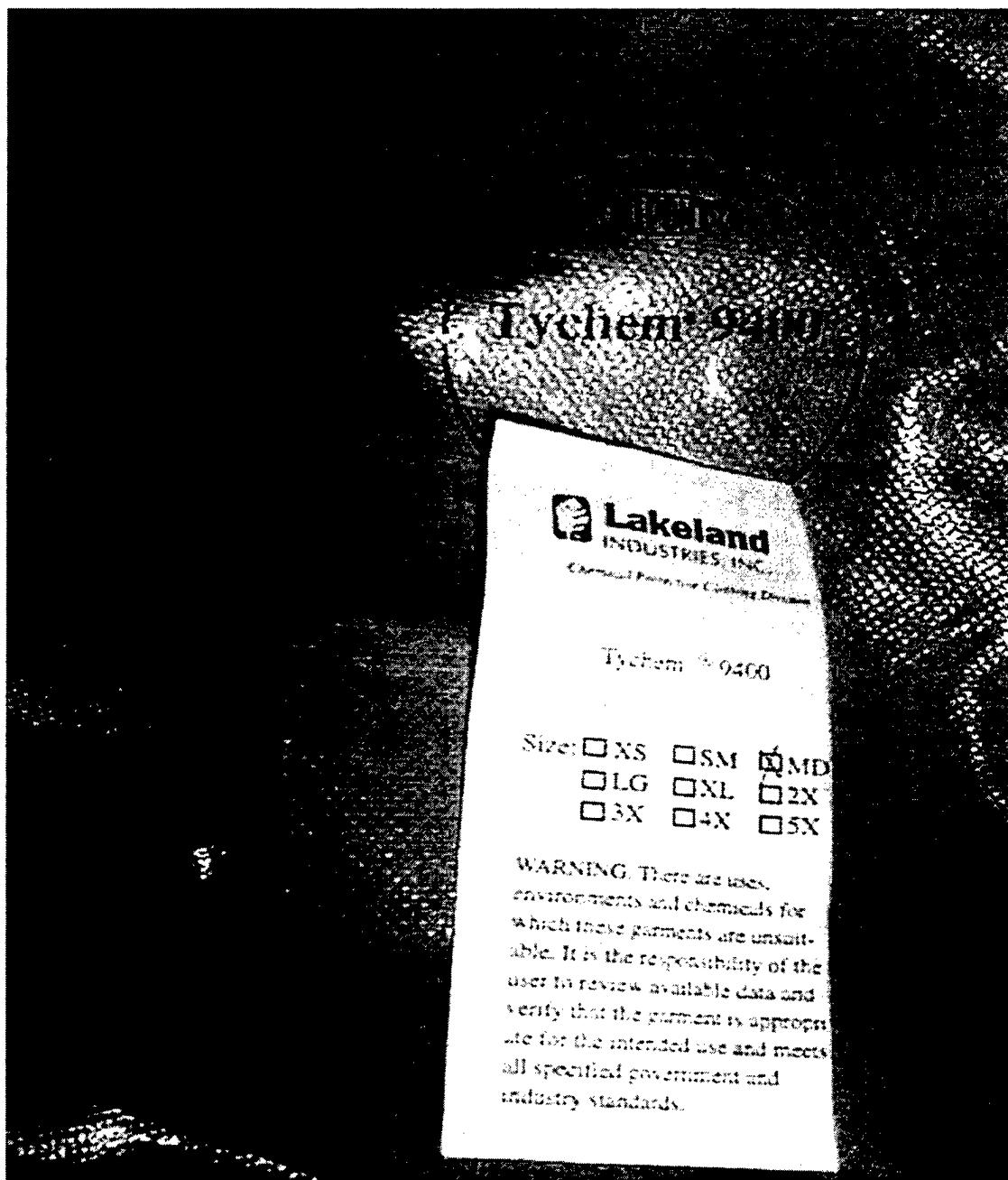


Figure 1. Tychem 9400 Label

The swatches were numbered in accordance with the PPE Test Team Work Instructions (written communication, R. Belmonte, Engineering Directorate, ERDEC, 11 June 1997); for example LC-TYC-SM-01, etc. All swatches were cut in triplicate, one at a time on a sample press. The swatch diameter was 2 in.

The reference material was 80-mil silicone, using the M45 mask formulation, prepared by Malcolm Little of the M45 mask team. Preparation and conditioning were the same as for the suit swatches.

2.3

Test Procedure.

The procedure agreed upon by ERDEC and NRDEC was derived from the report entitled, "Permeation and Penetration Testing of Air Permeable, Semi-permeable and Impermeable Materials with Chemical Agents or Simulants (Swatch Testing)" dated 3 March 1997. The Modified Static Diffusion Procedure is found in Appendix A of this report. Subsequent to the agreement, ERDEC personnel determined that the usage of the 80-mil silicone did not meet the definition of a positive control. The silicone swatches were used as an indication of agent vapor permeation. Equipment and schedule limitations prevented the use of negative controls. The terminology of the test procedure was not modified to reflect these changes.

The TOP permeation cell was used and a digital photograph of one is given as Figure 2.

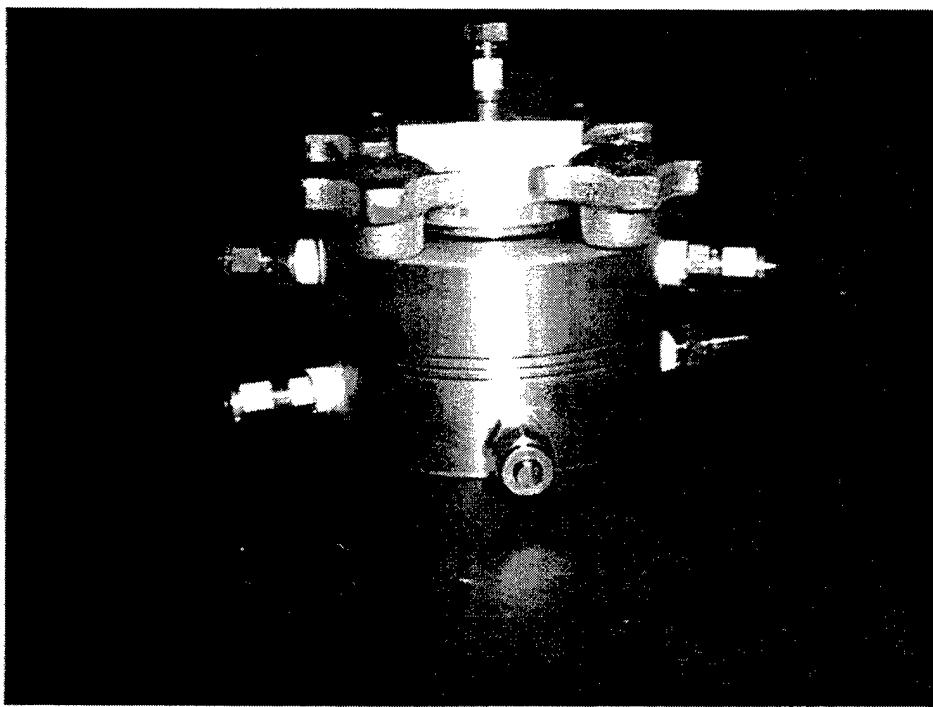


Figure 2. TOP Permeation Cell

The remainder of the test apparatus consisted of the following.

- Plastic environmental cabinet with sliding doors containing a permeation cell rack, circulating blower, and heat source (Figure 3).
- Flow/temperature/relative humidity control system; (Miller-Nelson Research Corporation, Monterey, CA) model HCS-410.

- Flow control system; (Tylan General Incorporated, Torrance, CA) Dynamass model FM-8.
- Mass flow controllers; (Tylan General Incorporated, Torrance, CA) model FC-260.
- Calibrated Vaisala humidity and temperature indicator.
- MINICAMS, serial number 1860, and Stream Selection System (CMS Research Corporation, Birmingham, AL). Illustrated in Figure 4.

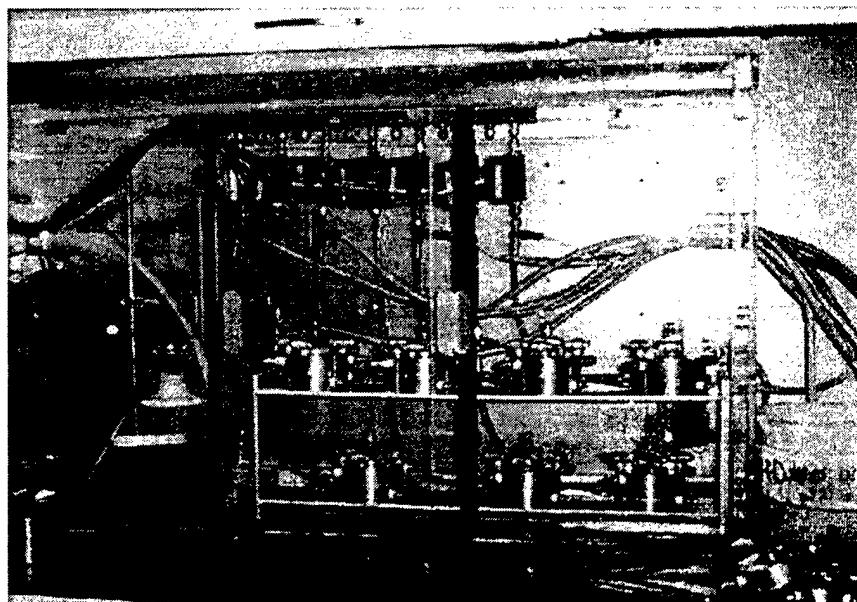


Figure 3. Environmental Cabinet

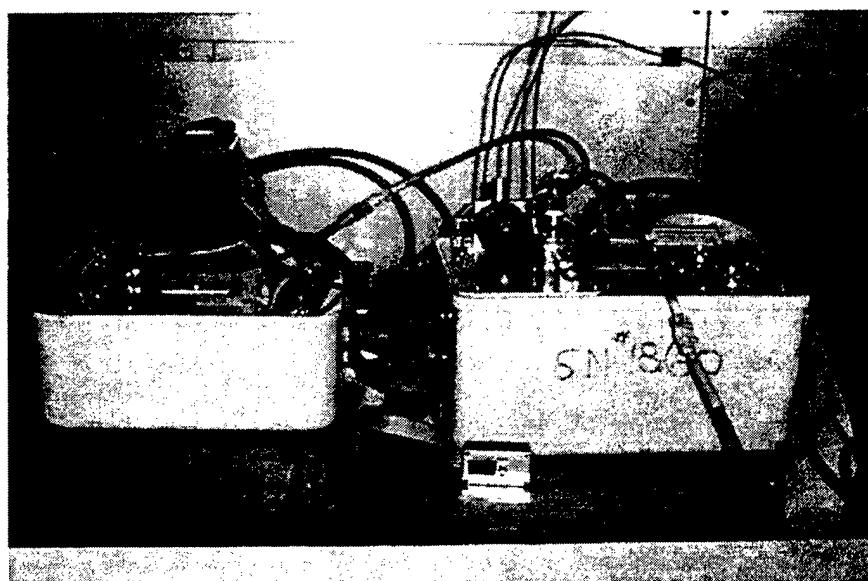


Figure 4. MINICAMS and Stream Selection System

3. RESULTS AND DISCUSSION

3.1 HD Results.

The HD permeation results are given in Appendix B as Tables B-1 through B-6. Average elapsed time was not used. The actual time that each swatch was sampled by the MINICAMS is shown.

The MINICAMS minimum detection limit was 1.0 ng for all test days. There were no visible effects on any of the materials from HD exposure. Cumulative permeation for one crotch seam swatch was significantly higher than the suit material. Cumulative permeation for all other swatches was similar to or less than that for the suit material.

The average temperature was 88.7 °F, and 50.3% RH was the average for all tests. The first MINICAMS cycle for each swatch was taken before agent was applied. This cycle served as an indication that no agent vapor was present prior to the start of the test. Negative control and positive control swatches were not used.

3.2 GB Results.

The GB permeation results are given in Appendix C as Tables C-1 through C-6.

The MINICAMS minimum detection limit was 0.4 ng for all test days. There were no visible effects on any of the materials from GB exposure. Cumulative permeation was highest for two outer zipper/material interface and two crotch seam swatches (several times higher than for the suit material).

The average temperature was 88.7 °F and 49.3% RH was the average for all tests. The first MINICAMS cycle for each swatch was taken before agent was applied. This cycle served as an indication that no agent vapor was present prior to the start of the test. Negative control and positive control swatches were not used.

3.3 Material Thickness.

Prior to conducting the HD and GB testing, thickness measurements of the suit material and the boot material were made. A swatch of material was cut from the suit immediately adjacent to the area from which the agent swatches were taken. Twenty-four thickness measurements were taken on each swatch using an Ames dial comparator (B. C. Ames Company, Waltham, MA). The average thickness of the suit material swatch was 0.022 in. and the boot material swatch was 0.021 in.

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APPENDIX A
MODIFIED STATIC DIFFUSION PROCEDURE

MODIFIED STATIC DIFFUSION TEST

This test procedure was adapted from the "Semipermeable and Impermeable Materials Static Diffusion Penetration Testing (Liquid Agent Challenge/Vapor Penetration; delta p = 0, Single Flow Test) given in Test Operations Procedure (TOP) 8-2-501 dated 3 Mar 97.

The following procedure will be used:

Upon receipt of a suit, all available information concerning the suit will be recorded; date of manufacture, lot number, serial number, materials of construction, etc.

From each suit, 3 ea 1 and 15/16 in. diameter material swatches will be taken for HD and a like number taken for GB. Depending upon the suit configuration, three seam swatches (same diameter) will be taken plus triplicate swatches of other flat components such as other seams, visor, gloves, booties, etc. for HD and an equal number for GB. Each swatch will be placed in an airtight bag and given a unique serial number which will be placed on the bag. A list of serial numbers will be kept with the swatches.

The environmental chamber will be controlled at a temperature of 90 +/- 2 °F, and the maximum achievable RH without occurrence of condensation (70% +/- 10% RH). The temperature and RH readings will be checked weekly with a calibrated meter. The test cell air will be drawn from the chamber air. There will be no system control and data acquisition system. The temperature and RH will be recorded in a computer file. Flow rates will be manually recorded. There will be no differential pressure monitoring since differential pressure gages of sufficient sensitivity are not available.

The TOP test cell will be used. When assembling, the cell lugs will be tightened by hand to finger tight. The flow rate beneath each swatch will be 1 L/min which will be controlled by a linear mass flow controller. The flows will be checked with a calibrated test meter weekly. Each test cell will be checked for leaks after assembly by connecting it to the vacuum source and checking that the inlet flow is the same as the outlet flow on the mass flow controller (cell lugs will be retightened if flows don't match).

The samples will serve as their own negative controls while being preconditioned overnight by being MINICAMS monitored. Eighty mil silicone will be used as a positive control for each test (six suit swatches and one silicone swatch).

Agents GB and HD will be used. The contamination density will be 10 g/m² (eight each 1 µl HD droplets or ten each 1 µl GB droplets). A robotic agent application system is not available. The agent will be applied using the click/touch method with a Hamilton repeating dispenser.

Seven swatches will be tested at once. MINICAMS with stream selection system will monitor vapor penetration with a 3-min cycle. There will be three blank sampling intervals following the control. Each swatch will be sampled once every 30 min. The MINICAMS will be standardized weekly.

The test length will be 24 hr.

The test cells and o-rings will be aerated between uses. No other cleaning method will be used.

The data to be reported are cumulative penetration (ng/cm²) versus average elapsed time (minutes) for each swatch. The average elapsed time is the sum of the elapsed time for swatch 1 and the elapsed time for swatch 6 divided by 2. All recorded data will be placed in laboratory notebooks and a technical report will be drafted at the conclusion of this effort.

For entry into the DP database, the data for each swatch will be reported as cumulative penetration for the first four sampling intervals (approximately 12, 42, 72 and 102 min), at approximately 6, 12, 18, and 24 hr.

Appendix A

APPENDIX B
HD TABLES

Table B-1. Lakeland Tychem 9400 Coverall Suit Material vs. HD Liquid, 10 g/m²
Modified Static Diffusion Test, 12 May 1998
Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
2	0	5	1	8	1
33	5	36	4	39	5
63	5	66	4	69	5
93	5	96	4	99	5
124	5	127	4	130	5
154	7	157	4	160	5
184	12	187	4	190	8
215	18	218	6	221	12
245	25	248	12	251	18
275	32	278	18	281	23
306	41	309	24	312	29
336	49	339	31	342	36
366	57	369	38	372	42
397	66	400	45	403	48
427	74	430	51	433	54
457	83	460	58	463	60
488	91	491	65	494	66
518	99	521	71	524	72
548	107	551	77	554	78
579	114	582	84	585	84
609	122	612	90	615	90
639	130	642	96	645	96
670	137	673	102	676	102
700	144	703	108	706	107
730	151	733	113	736	112
761	158	764	119	767	118
791	165	794	125	797	123
821	171	824	130	827	128
852	178	855	135	858	133
882	184	885	140	888	138
912	190	915	146	918	143
943	197	946	150	949	148
973	202	976	155	979	154
1003	208	1006	160	1009	158
1034	214	1037	165	1040	161
1064	219	1067	170	1070	163
1094	224	1097	174	1100	165
1125	230	1128	179	1131	165
1155	235	1158	183	1161	165
1185	240	1188	186	1191	165
1216	245	1219	186	1222	165
1246	250	1249	186	1252	165
1276	255	1279	186	1282	165
1307	259	1310	186	1313	165
1337	264	1340	186	1343	165
1367	268	1370	186	1373	165
1398	271	1401	186	1404	165

Appendix B

Table B-2. Lakeland Tychem 9400 Coverall Suit Seam vs. HD Liquid, 10 g/m²
Modified Static Diffusion Test, 12 May 1998
Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
11	1	14	2	17	2
42	4	45	5	48	5
72	4	75	5	78	5
102	4	105	5	108	5
133	4	136	5	139	5
163	4	166	5	169	5
193	7	197	5	200	5
224	12	227	8	230	5
254	17	257	10	260	5
284	22	288	12	291	5
315	28	318	17	321	7
345	33	348	22	351	9
375	39	379	28	382	11
406	45	409	33	412	16
436	51	439	38	442	21
466	56	470	43	473	26
497	62	500	48	503	30
527	68	530	54	533	35
557	74	561	59	564	40
588	80	591	64	594	45
618	85	621	69	624	49
648	91	652	74	655	54
679	97	682	79	685	56
709	102	712	84	715	56
739	108	743	88	746	56
770	113	773	93	776	56
800	118	803	98	806	56
830	123	834	100	837	56
861	128	864	102	867	56
891	132	894	107	897	56
921	137	925	109	928	56
952	142	955	109	958	56
982	147	985	109	988	56
1012	151	1016	109	1019	56
1043	156	1046	109	1049	56
1073	158	1076	111	1079	56
1103	158	1107	116	1110	56
1134	158	1137	118	1140	56
1164	161	1167	118	1170	56
1194	163	1198	118	1201	56
1225	163	1228	118	1231	56
1255	163	1258	118	1261	56
1285	163	1289	118	1292	56
1316	163	1319	118	1322	56
1346	163	1349	118	1352	56
1376	163	1380	118	1383	56
1407	163	1410	118	1413	56

Appendix B

Table B-3. Lakeland Tychem 9400 Boot Material vs. HD Liquid, 10 g/m²
Modified Static Diffusion Test, 14 May 1998
Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
2	0	5	0	8	1
32	0	35	6	38	3
62	0	65	12	68	3
93	0	96	17	99	3
123	2	126	24	129	3
153	7	156	31	159	5
184	14	187	40	190	10
214	22	217	49	220	16
244	31	247	59	250	23
275	40	278	70	281	31
305	51	308	82	311	39
335	62	338	94	341	47
366	74	369	106	372	56
396	87	399	119	402	65
426	99	429	131	432	74
457	110	460	143	463	83
487	122	490	154	493	92
517	133	520	166	523	100
548	144	551	177	554	108
578	155	581	188	584	116
608	166	611	198	614	124
639	176	642	208	645	132
669	186	672	218	675	139
699	196	702	227	705	147
730	205	733	237	736	155
760	214	763	246	766	162
790	223	793	255	796	169
821	232	824	263	827	176
851	241	854	272	857	183
881	250	884	281	887	190
912	259	915	289	918	196
942	267	945	298	948	203
972	276	975	307	978	210
1003	285	1006	315	1009	217
1033	293	1036	324	1039	224
1063	302	1066	332	1069	231
1094	310	1097	340	1100	237
1124	319	1127	348	1130	244
1154	327	1157	356	1160	250
1185	335	1188	364	1191	257
1215	343	1218	371	1221	263
1245	351	1248	379	1251	270
1276	359	1279	387	1282	276
1306	366	1309	394	1312	282
1336	373	1339	400	1342	287
1367	380	1370	407	1373	292
1397	387	1400	413	1403	298
1427	393	1430	420	1433	303

Appendix B

Table B-4. Lakeland Tychem 9400 Boot Seam vs. HD Liquid, 10 g/m²
Modified Static Diffusion Test, 13 May 1998
Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
12	0	15	0	18	0
42	2	45	2	48	2
72	5	75	5	79	5
103	5	106	5	109	5
133	5	136	5	139	5
163	5	166	5	170	5
194	7	197	5	200	5
224	12	227	5	230	5
254	17	257	7	261	5
285	22	288	12	291	7
315	27	318	17	321	12
345	33	348	22	352	17
376	39	379	27	382	22
406	44	409	32	412	26
436	50	439	38	443	31
467	56	470	43	473	37
497	62	500	48	503	41
527	67	530	53	534	44
558	72	561	58	564	44
588	78	591	63	594	46
618	83	621	68	625	49
649	88	652	70	655	49
679	91	682	72	685	49
709	93	712	75	716	49
740	96	743	75	746	49
770	96	773	75	776	49
800	96	803	75	807	49
831	98	834	75	837	49
861	100	864	75	867	49
891	100	894	75	898	49
922	100	925	75	928	49
952	100	955	75	958	49
982	100	985	75	989	49
1013	100	1016	75	1019	49
1043	100	1046	75	1049	49
1073	100	1076	75	1080	49
1104	100	1107	75	1110	49
1134	100	1137	75	1140	49
1164	100	1167	75	1171	49
1195	100	1198	75	1201	49
1225	100	1228	75	1231	49
1255	100	1258	75	1262	49
1286	100	1289	78	1292	49
1316	100	1319	81	1322	49
1346	100	1349	81	1353	49
1377	100	1380	81	1383	49
1407	100	1410	81	1413	49

Appendix B

Table B-5. Lakeland Tychem 9400 Crotch Seam vs. HD Liquid, 10 g/m²
Modified Static Diffusion Test, 14 May 1998
Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
11	0	14	0	17	3
41	0	44	3	47	13
71	0	74	5	77	94
102	0	105	8	108	418
132	0	135	14	138	1003
162	0	165	20	168	1694
193	2	196	28	199	2401
223	8	226	37	229	3133
253	14	256	47	259	3892
284	20	287	58	290	4656
314	27	317	70	320	5421
344	34	347	83	350	6189
375	42	378	98	381	6963
405	49	408	114	411	7745
435	57	438	130	441	8535
466	65	469	147	472	9334
496	73	499	164	502	10139
526	80	529	181	532	10953
557	87	560	198	563	11776
587	94	590	215	593	12604
617	101	620	233	623	13437
648	108	651	251	654	14279
678	115	681	270	684	15129
708	121	711	289	714	15979
739	128	742	309	745	16829
769	134	772	329	775	17679
799	140	802	349	805	18526
830	146	833	370	836	19376
860	152	863	391	866	20225
890	158	893	413	896	21069
921	164	924	435	927	21912
951	170	954	459	957	22754
981	176	984	483	987	23594
1012	182	1015	508	1018	24436
1042	188	1045	533	1048	25276
1072	194	1075	558	1078	26116
1103	200	1106	584	1109	26953
1133	206	1136	611	1139	27783
1163	211	1166	638	1169	28611
1194	217	1197	666	1200	29436
1224	223	1227	696	1230	30263
1254	229	1257	726	1260	31083
1285	234	1288	756	1291	31893
1315	237	1318	782	1321	32696
1345	237	1348	807	1351	33493
1376	237	1379	831	1382	34297
1406	237	1409	855	1412	35107

Appendix B

Table B-6. Lakeland Tychem 9400 Coverall Outer Zipper/Material Interface vs. HD Liquid, 10 g/m²
 Modified Static Diffusion Test, 13 May 1998
 Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
3	0	6	0	9	0
33	0	36	0	39	0
63	0	66	0	69	0
94	0	97	0	100	0
124	2	127	0	130	0
154	7	157	2	160	2
185	13	188	8	191	7
215	19	218	13	221	13
245	26	248	19	251	18
276	34	279	26	282	24
306	42	309	32	312	31
336	51	339	39	342	37
367	60	370	47	373	44
397	69	400	54	403	50
427	79	430	62	433	57
458	88	461	69	464	64
488	97	491	77	494	71
518	106	521	84	524	77
549	115	552	90	555	83
579	123	582	97	585	89
609	131	612	104	615	96
640	139	643	110	646	102
670	147	673	117	676	108
700	155	703	123	706	113
731	163	734	129	737	119
761	170	764	135	767	124
791	177	794	141	797	129
822	184	825	147	828	135
852	191	855	152	858	140
882	198	885	158	888	145
913	205	916	164	919	150
943	212	946	169	949	155
973	218	976	174	979	160
1004	225	1007	180	1010	165
1034	231	1037	185	1040	170
1064	237	1067	190	1070	175
1095	243	1098	194	1101	179
1125	249	1128	199	1131	184
1155	255	1158	204	1161	189
1186	261	1189	209	1192	193
1216	267	1219	214	1222	198
1246	272	1249	218	1252	202
1277	278	1280	223	1283	207
1307	283	1310	225	1313	209
1337	288	1340	225	1343	209
1368	293	1371	225	1374	209
1398	298	1401	225	1404	209
1428	302	1431	225	1434	209

Appendix B

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APPENDIX C
GB TABLES

Table C-1. Lakeland Tychem 9400 Coverall Suit Material vs. GB Liquid, 10 g/m²
Modified Static Diffusion Test, 20 May 1998
Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
11	0	14	1	17	0
42	33	45	29	48	42
72	117	75	94	78	132
103	212	106	166	109	216
133	291	136	230	139	282
163	357	166	290	170	342
194	417	197	345	200	398
224	468	227	394	230	446
254	511	257	438	261	488
285	550	288	478	291	525
315	584	318	513	321	559
345	614	348	544	352	589
376	640	379	573	382	616
406	664	409	599	412	640
436	687	439	622	443	663
467	708	470	644	473	683
497	727	500	665	503	703
527	744	530	683	534	720
558	760	561	700	564	736
588	775	591	716	594	752
618	789	621	730	625	766
649	801	652	743	655	779
679	813	682	756	685	791
709	825	712	767	716	802
740	835	743	778	746	813
770	845	773	788	776	823
800	854	803	797	807	832
831	863	834	806	837	841
861	871	864	814	867	849
891	879	894	823	898	857
922	888	925	832	928	865
952	896	955	840	958	873
982	904	985	847	989	880
1013	911	1016	853	1019	887
1043	918	1046	859	1049	893
1073	924	1076	865	1080	899
1104	930	1107	871	1110	904
1134	936	1137	876	1140	910
1164	942	1167	880	1171	915
1195	947	1198	885	1201	920
1225	952	1228	889	1231	925
1255	957	1258	894	1262	929
1286	962	1289	896	1292	934
1316	966	1319	896	1322	938
1346	971	1349	896	1353	942
1377	975	1380	896	1383	944
1407	979	1410	896	1413	944

Appendix C

Table C-2. Lakeland Tychem 9400 Coverall Suit Seam vs. GB Liquid, 10 g/m²
Modified Static Diffusion Test, 20 May 1998
Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
2	0	5	0	8	0
33	30	36	35	39	27
63	108	66	125	69	101
94	194	97	227	100	187
124	265	127	314	130	254
154	328	157	387	160	310
185	382	188	450	191	358
215	429	218	503	221	396
245	469	248	549	251	427
276	503	279	589	282	453
306	534	309	625	312	474
336	562	339	656	342	494
367	587	370	685	373	511
397	610	400	710	403	526
427	631	430	733	433	539
458	650	461	754	464	552
488	667	491	773	494	563
518	683	521	790	524	573
549	698	552	806	555	583
579	712	582	820	585	592
609	725	612	834	615	600
640	737	643	847	646	608
670	748	673	859	676	615
700	758	703	870	706	622
731	768	734	880	737	628
761	778	764	890	767	634
791	787	794	899	797	639
822	795	825	908	828	644
852	802	855	916	858	649
882	810	885	924	888	654
913	817	916	931	919	659
943	825	946	939	949	661
973	832	976	945	979	661
1004	839	1007	952	1010	661
1034	845	1037	958	1040	661
1064	852	1067	964	1070	661
1095	857	1098	970	1101	661
1125	863	1128	975	1131	661
1155	868	1158	980	1161	661
1186	874	1189	985	1192	661
1216	879	1219	990	1222	661
1246	883	1249	995	1252	661
1277	888	1280	999	1283	661
1307	892	1310	1003	1313	661
1337	897	1340	1005	1343	661
1368	901	1371	1005	1374	661
1398	905	1401	1005	1404	661
1428	907	1431	1005	1434	661

Appendix C

Table C-3. Lakeland Tychem 9400 Coverall Boot Material vs. GB Liquid, 10 g/m²
Modified Static Diffusion Test, 18 May 1998
Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
2	0	5	0	8	0
32	10	35	13	38	14
62	82	65	82	68	75
92	178	95	171	98	152
123	235	126	227	129	204
153	276	156	268	159	242
183	310	186	303	189	273
213	339	216	334	219	299
244	364	247	361	250	321
274	387	277	385	280	341
304	407	307	406	310	357
334	424	337	425	340	372
364	440	367	443	370	386
395	455	398	459	401	398
425	471	428	475	431	410
455	486	458	490	461	421
485	501	488	504	491	432
515	515	519	518	522	443
546	528	549	531	552	454
576	540	579	543	582	465
606	552	609	555	612	475
636	563	639	566	642	485
667	574	670	577	673	495
697	585	700	588	703	505
727	595	730	598	733	515
757	605	760	608	763	524
787	614	790	617	793	533
818	622	821	626	824	542
848	631	851	635	854	550
878	639	881	643	884	558
908	647	911	652	914	566
939	654	942	659	945	574
969	662	972	667	975	581
999	669	1002	674	1005	588
1029	675	1032	682	1035	595
1060	683	1063	689	1066	602
1090	690	1093	697	1096	610
1120	698	1123	705	1126	618
1150	705	1153	713	1156	625
1181	713	1184	720	1187	632
1211	720	1214	728	1217	639
1241	727	1244	735	1247	645
1271	733	1274	741	1277	652
1302	740	1305	748	1308	658
1332	746	1335	754	1338	664
1362	752	1365	761	1368	669
1392	758	1395	767	1398	675
1423	763	1426	773	1429	681

Appendix C

Table C-4. Lakeland Tychem 9400 Coverall Boot Seam vs. GB Liquid, 10 g/m²
Modified Static Diffusion Test, 21 May 1998
Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
9	2	13	9	16	8
40	19	43	61	46	41
70	50	73	127	76	79
100	96	103	202	106	116
131	150	134	278	137	150
161	209	164	350	167	182
191	273	194	416	197	210
221	343	224	480	227	236
252	418	255	544	258	261
282	501	285	606	288	291
312	591	315	665	318	326
342	683	345	720	348	358
373	774	376	771	379	389
403	858	406	819	409	416
433	939	436	862	439	443
463	1018	466	902	469	468
494	1086	497	940	500	492
524	1142	527	974	530	514
554	1194	557	1006	560	536
584	1246	587	1037	590	556
615	1297	618	1065	621	576
645	1348	648	1095	651	594
675	1398	678	1124	681	612
705	1446	708	1152	711	629
736	1492	739	1178	742	645
766	1537	769	1201	772	661
796	1579	799	1223	802	675
827	1621	830	1244	833	689
857	1662	860	1263	863	702
887	1700	890	1282	893	715
917	1738	921	1299	924	727
948	1774	951	1315	954	738
978	1808	981	1330	984	748
1008	1841	1012	1345	1015	759
1039	1872	1042	1359	1045	769
1069	1902	1072	1371	1075	778
1099	1930	1102	1384	1105	786
1130	1957	1133	1395	1136	795
1160	1983	1163	1406	1166	803
1190	2007	1193	1417	1196	811
1221	2031	1224	1427	1227	818
1251	2054	1254	1436	1257	825
1281	2076	1284	1445	1287	832
1312	2096	1315	1454	1318	838
1342	2116	1345	1462	1348	845
1372	2134	1375	1470	1378	851
1403	2153	1406	1478	1409	857
1433	2170	1436	1485	1439	863

Appendix C

Table C-5. Lakeland Tychem 9400 Coverall Crotch Seam vs. GB Liquid, 10 g/m²

Modified Static Diffusion Test, 18 May 1998

Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
11	0	14	0	17	0
41	180	44	239	47	222
71	605	74	686	77	541
102	1103	105	1093	108	708
132	1608	135	1506	138	835
162	2111	165	1927	168	936
192	2606	195	2331	198	1024
222	3095	225	2721	228	1105
253	3578	256	3099	259	1181
283	4065	286	3479	289	1255
313	4551	316	3864	319	1329
343	5028	346	4245	349	1408
373	5493	376	4613	379	1496
404	5950	407	4969	410	1586
434	6409	437	5247	440	1651
464	6867	467	5455	470	1689
494	7311	497	5654	500	1725
525	7743	528	5844	531	1759
555	8166	558	6028	561	1791
585	8585	588	6209	591	1822
615	9001	618	6385	621	1852
645	9414	648	6555	651	1879
676	9821	679	6719	682	1905
706	10221	709	6877	712	1931
736	10614	739	7033	742	1955
766	11000	769	7185	772	1978
797	11378	800	7333	803	2000
827	11745	830	7476	833	2021
857	12097	860	7612	863	2042
887	12434	890	7742	893	2062
917	12756	920	7866	923	2081
948	13069	951	7985	954	2099
978	13372	981	8099	984	2116
1008	13662	1011	8210	1014	2134
1038	13941	1041	8316	1044	2150
1069	14171	1072	8422	1075	2164
1099	14350	1102	8525	1105	2177
1129	14525	1132	8621	1135	2189
1159	14700	1162	8715	1165	2202
1190	14873	1193	8807	1196	2214
1220	15045	1223	8898	1226	2225
1250	15216	1253	8987	1256	2237
1280	15386	1283	9073	1286	2248
1311	15554	1314	9157	1317	2258
1341	15721	1344	9239	1347	2269
1371	15886	1374	9321	1377	2279
1401	16048	1404	9399	1407	2289
1432	16210	1435	9474	1438	2298

Appendix C

Table C-6. Lakeland Tychem 9400 Coverall Outer Zipper/Material Interface vs. GB Liquid, 10 g/m²
 Modified Static Diffusion Test, 21 May 1998

Cumulative Penetration (ng/cm ²)					
Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
0	0	3	1	6	2
31	5	34	21	37	20
61	27	64	77	67	71
91	63	94	202	97	184
122	99	125	384	128	366
152	130	155	615	158	604
182	157	185	877	188	885
212	179	215	1161	218	1210
242	201	246	1476	249	1574
273	228	276	1821	279	1961
303	255	306	2172	309	2354
333	281	336	2526	339	2740
363	306	366	2884	370	3123
394	329	397	3244	400	3504
424	351	427	3603	430	3882
454	371	457	3963	460	4254
485	391	488	4323	491	4621
515	410	518	4681	521	4985
545	430	548	5038	551	5350
575	449	578	5391	581	5716
606	467	609	5740	612	6083
636	484	639	6082	642	6454
666	500	669	6414	672	6823
696	516	699	6736	702	7182
727	532	730	7050	733	7538
757	546	760	7357	763	7893
787	560	790	7657	793	8245
817	573	820	7950	824	8593
848	586	851	8238	854	8940
878	598	881	8521	884	9285
908	610	911	8793	914	9625
939	621	942	9055	945	9959
969	632	972	9312	975	10289
999	643	1002	9563	1005	10614
1030	654	1033	9805	1036	10933
1060	663	1063	10039	1066	11244
1090	672	1093	10268	1096	11546
1121	681	1124	10488	1127	11840
1151	689	1154	10699	1157	12126
1181	697	1184	10903	1187	12402
1212	704	1215	11100	1218	12668
1242	712	1245	11294	1248	12924
1272	719	1275	11480	1278	13168
1302	726	1306	11660	1309	13401
1333	732	1336	11832	1339	13626
1363	739	1366	11999	1369	13847
1393	745	1397	12163	1400	14063
1424	751	1427	12320	1430	14269

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